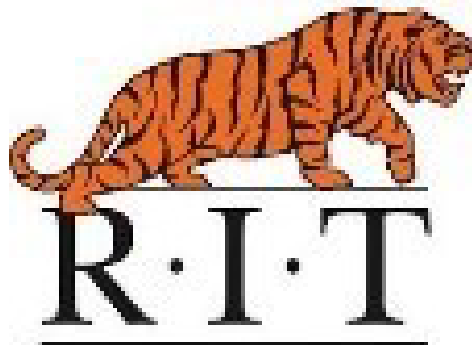


**Some comments on US electromobility
and
TESSA (Techno-Economic Study of Second-
life battery for Affordable e-mobility campus)**

**Pr. Eric HITTINGER
Director, School of Public Affairs
Rochester Institute of Technology (USA)**



The US is a car-centered country, so EVs are the prominent alternative

US trip distance by mode (person-km) (1)

Personal Vehicle	School Bus	Public Transit	Bike+Walk	Air
86%	3%	2%	1%	8%

EU trip distance by mode (person-km) (2)

Personal Vehicle	School Bus	Public Transit + Train	Bike+Walk	Air
56%	-	27%	3%	10%

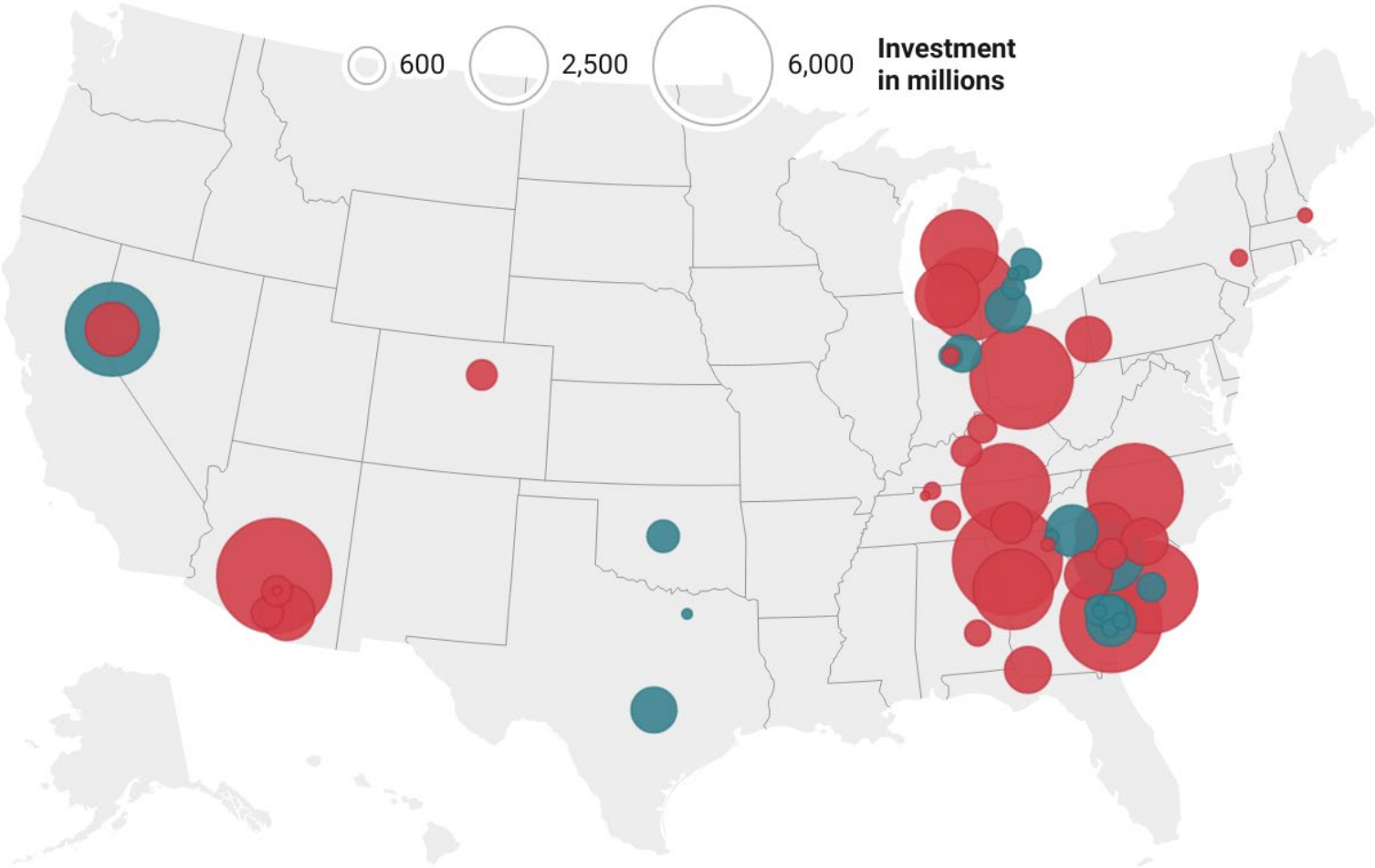
1: https://www.fhwa.dot.gov/policyinformation/pubs/our_nations_highways_2026/travel.cfm

2: <https://www.sciencedirect.com/science/article/pii/S2352146516301831/pdf?md5=b487395dc35b2ed28a6d9dacab4c63cb&pid=1-s2.0-S2352146516301831-main.pdf>

US EV sales are a political story

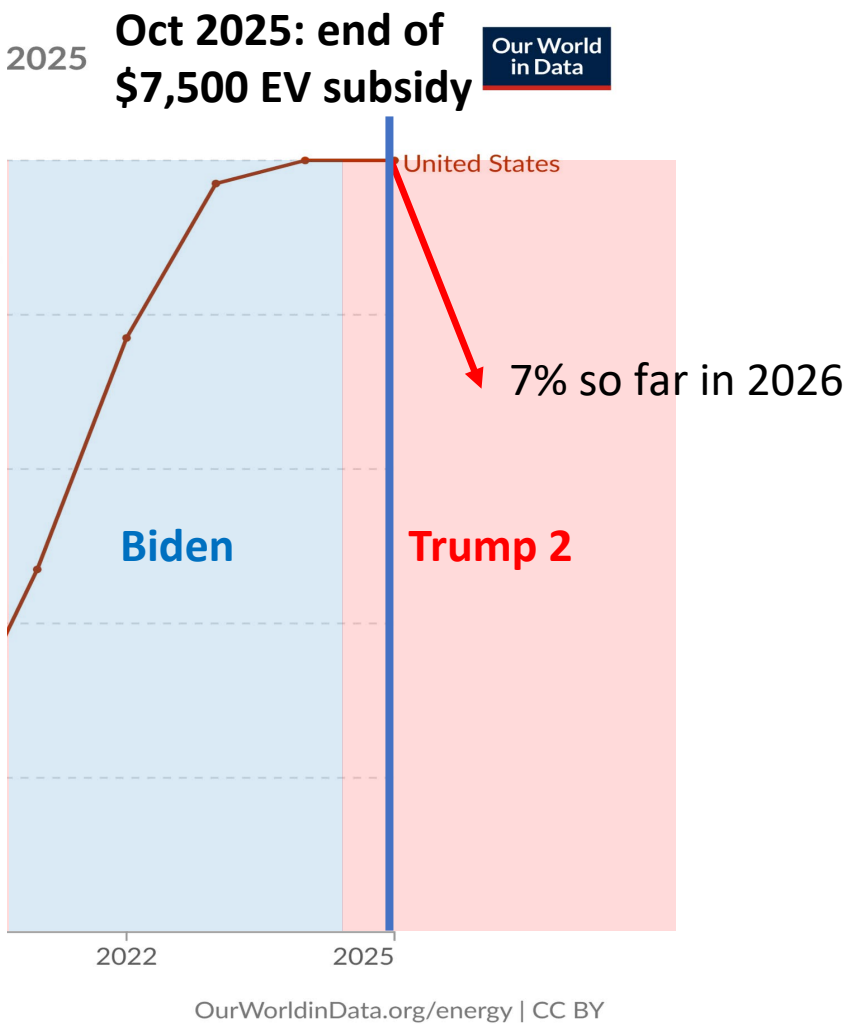
New planned factories or expansions unveiled from August 2022 to May 2023

■ Batteries ■ Electric vehicles



Map: Canary Media

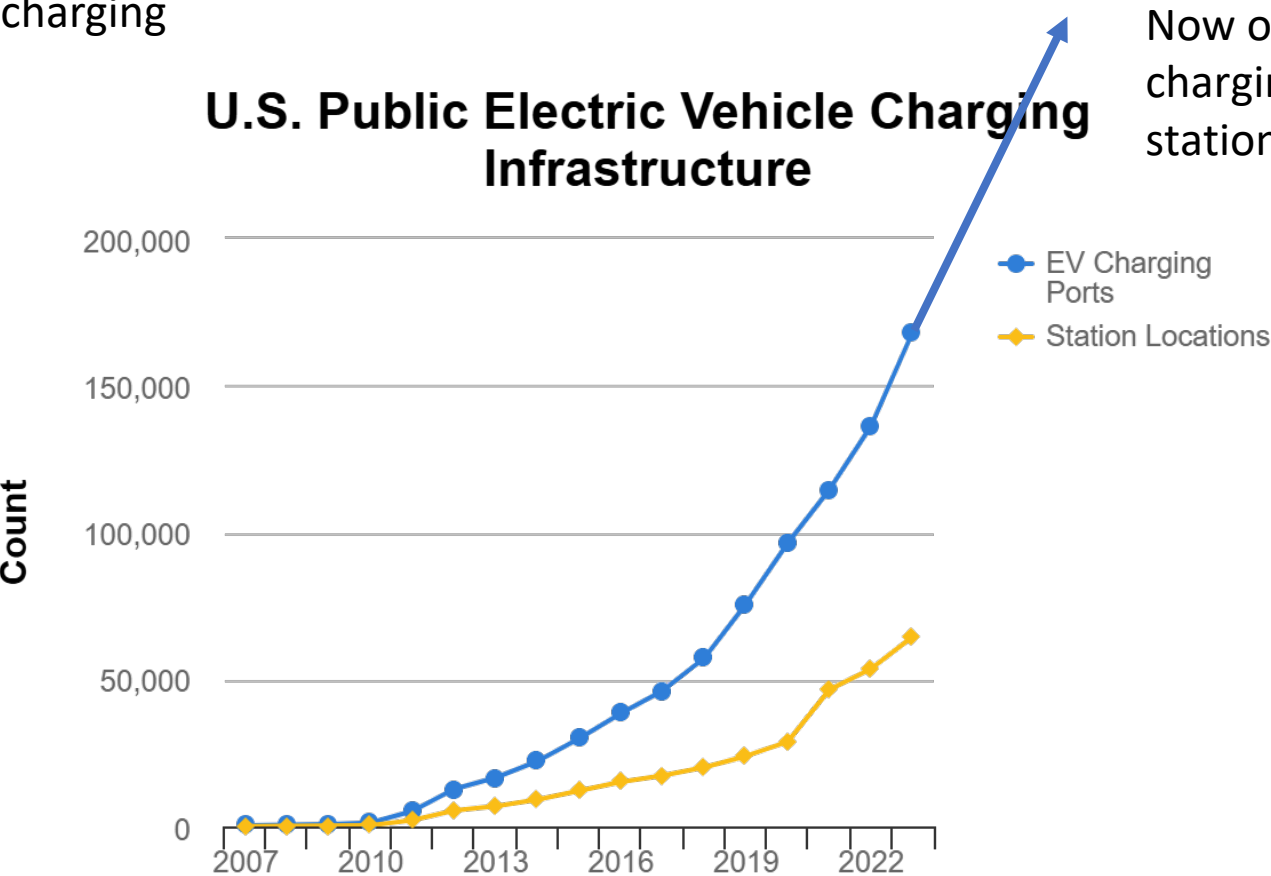
once the battery has run out.



nd battery, instead of an internal combustion engine.
d an internal combustion engine.
ver longer distances, the car starts running on gasoline

Growth in EV chargers is a success story in the US

Biden-era laws (Bipartisan Infrastructure Law and Inflation Reduction Act) set aside ~\$10B for EV chargers, mainly fast charging



Now over 250,000 – more charging points than gas stations!

Level 2 Chargers

**69,822**
Station Locations

 Download Station Locations 

**185,757**
EV Charging Ports 

DC Fast Chargers

**16,359**
Station Locations

 Download Station Locations 

**80,214**
EV Charging Ports 

Last updated: March 2024
Printed on: October 10, 2026

Highcharts.com

<https://afdc.energy.gov/data/10972>

Other technologies are growing, but are generally behind other countries

- E-bikes are now 10% of US bicycle sales (compared with 50% in Germany)
- E-buses have doubled in 5 years, but are still only ~20% of the public bus fleet
- Many of the leading electric aviation companies are in the US, with a large potential market (90% of US airplanes are small, non-commercial planes)

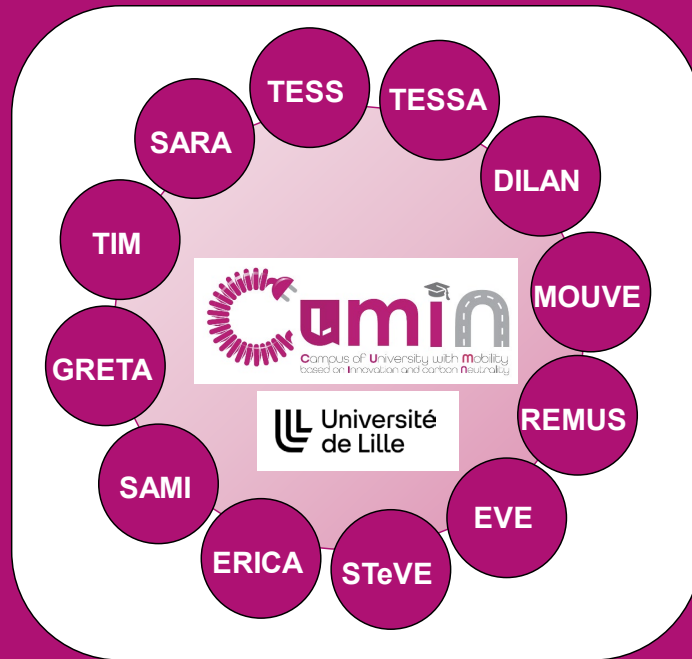
<https://www.peopleforbikes.org/news/e-bike-market-bigger-than-numbers-show>

https://www.faa.gov/air_traffic/by_the_numbers



CUMIN - TESSA

<https://cumin.univ-lille.fr/>



Techno-Economic Study of Second-life battery for Affordable e-mobility campus

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R.I.T

L2EP
Laboratoire d'électrotechnique et d'électronique de puissance de Lille

TVES
Territoires Villes Environnement & Société 44 4077

LaM^{CUBE}
Laboratoire de mécanique, multiphysique, multiéchelle

CERSÉ

LOA
Laboratoire d'optique atmosphérique

Gériico

MEL

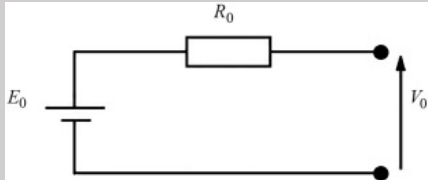
MÉTROPOLÉ
EUROPÉENNE DE LILLE

Agence Nationale de la Recherche
ANR

Région
Hauts-de-France

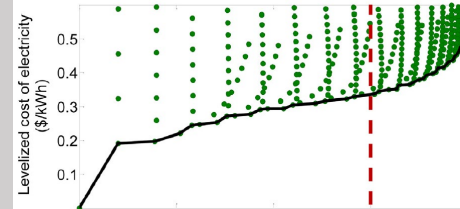
1. How should second-life EV batteries be operated to balance their economic and environmental benefits?

Technical Models



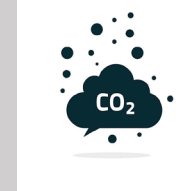
Battery performance = $f(\text{operation})$
Battery lifetime = $f(\text{operation})$

Economic Models



Economic value = $f(\text{operation}, \text{performance}, \text{lifetime}, \text{preferences})$

Environmental Assessment



Grid emissions effects = $f(\text{operation}, \text{performance})$
Embodied emissions = $f(\text{lifetime})$

Driver Behavior and Preferences

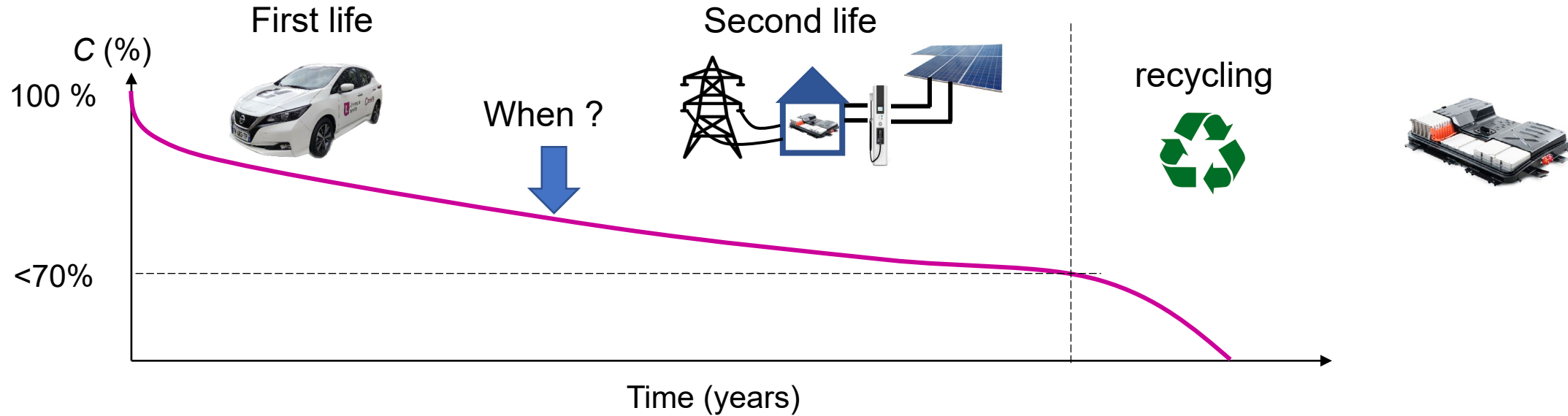


Integrated Framework

Economic value = $f(\text{operation}, \text{preferences})$

Net emissions effect = $f(\text{operation})$

2. If electric vehicle batteries have a useful second life, when should drivers replace them?



Consequences of battery aging:

- Acceleration is reduced
 - Driving range decreases
 - Losses increase
- These three consequences are grouped by a bracket and lead to two outcomes via magenta arrows:
- Lower driver satisfaction
 - Higher cost per km (consumption/recharge)



Similar phenomenon for mobile phone

Less autonomy

More frequent recharges

Grid applications may be less demanding on batteries than EVs. But can the economics of second-life batteries work?

The project uses an interdisciplinary framework to integrate technical, environmental, and behavioral/preference elements

Engineering

Environment

Driver

Second Life Value (SLV) = $C_{\text{alternative}}$

The market value of a used EV battery is equal to the cost of providing the same service from a new battery (using “Levelized Cost of Storage”)

This year



New battery = \$100/kWh (20 yr life)

Used EV battery @ 90% capacity and 15 yr life



Market value $\approx$
 $(\$100)(0.9)(0.75) = \$67.5/\text{kWh}$

Next year



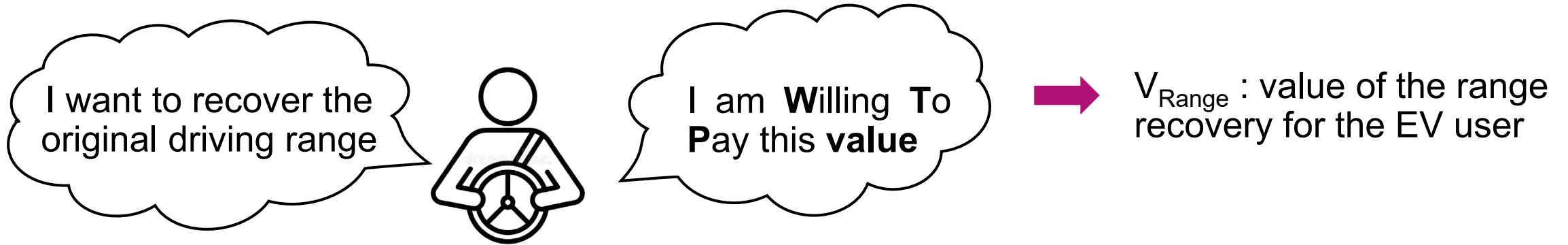
New battery = \$95/kWh (20 yr life)

Used EV battery @ 88% capacity and 14 yr life

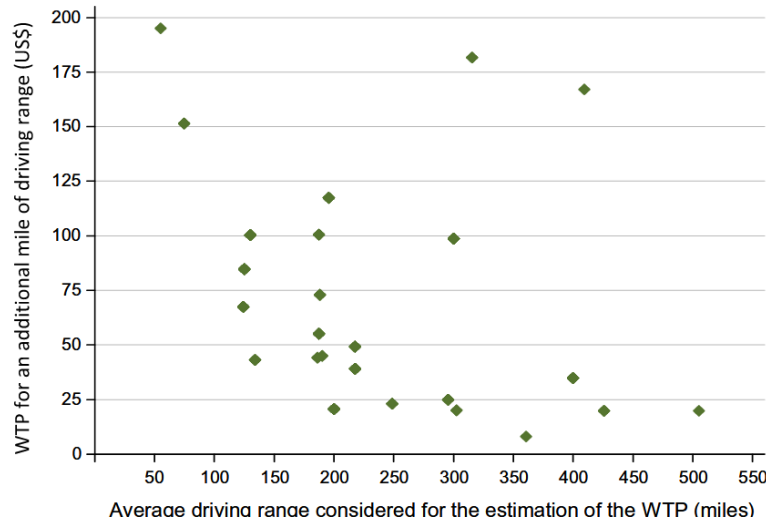
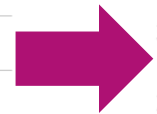
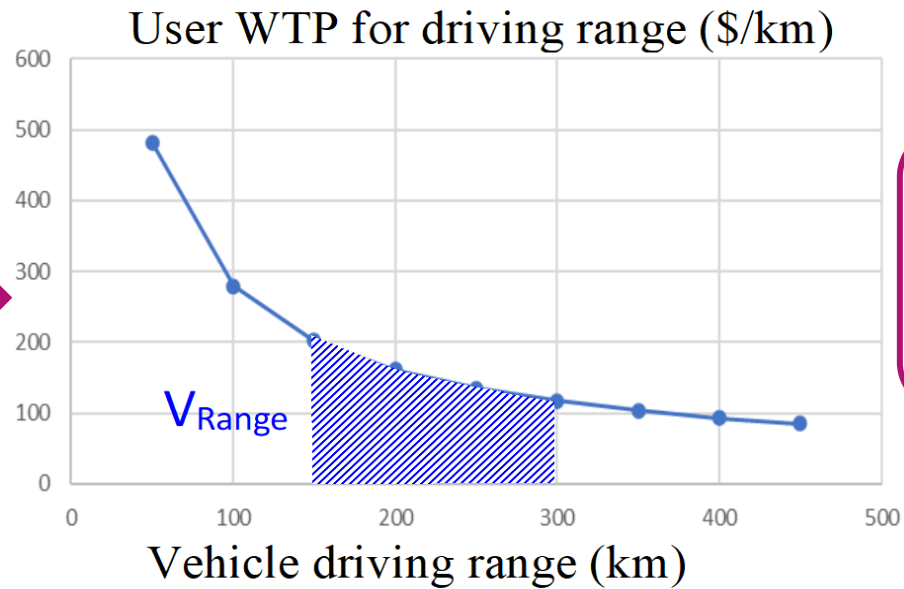


Market value $\approx$
 $(\$95)(0.88)(0.7) = \$58.5/\text{kWh}$

Drivers are willing to pay for improved performance of a new battery



[Dimitropoulos 2013]



$$V_{Range}(t) = \frac{1}{E_{Bat}} \int_{DR(0)}^{DR(t)} WTP(t)$$

7

Example for a 41kWh vehicle: 250km



300km

Replacement



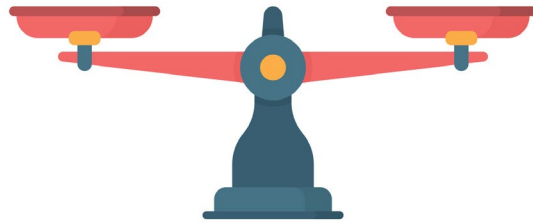
$V_{Range}(t) = 153\$/kWh$

But the vehicle life limits the utility of battery exchange in old EVs

Driving range recovery value is mitigated by the EV age

Driving Range

Vehicle Remaining Useful Life

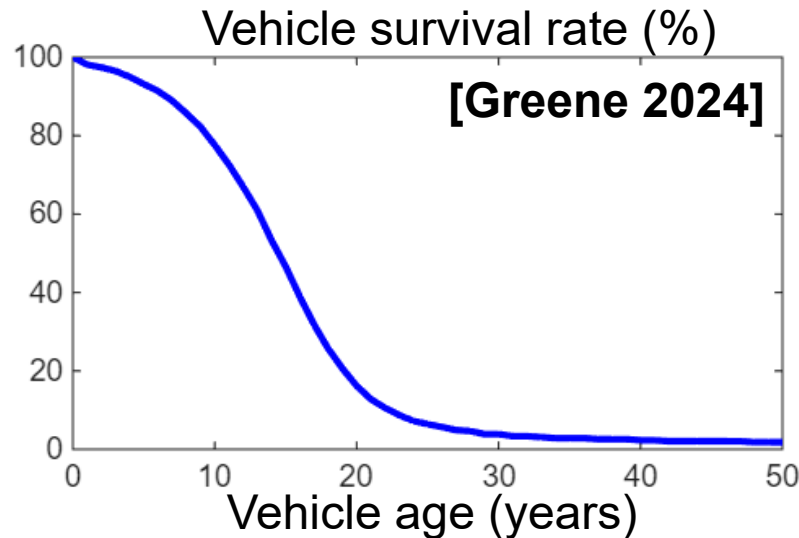


No reason to change battery if the EV is too old!

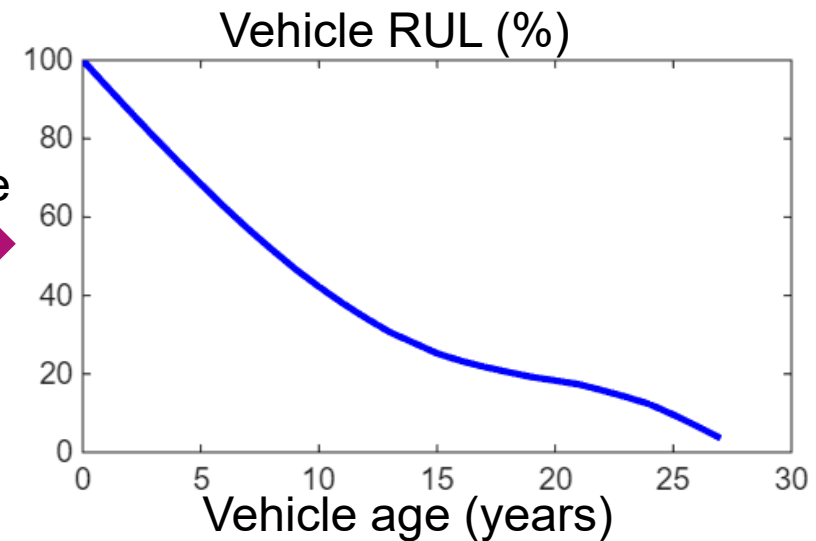
EV survival rate



Proportion of vehicles not discarded by t years



Actuarial table

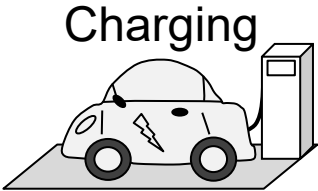


We can bring in the technical model to understand battery aging (case study)

- Usage scenario

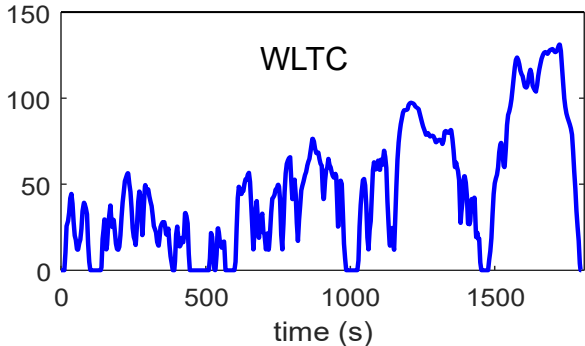


2x/day



Every 3 days

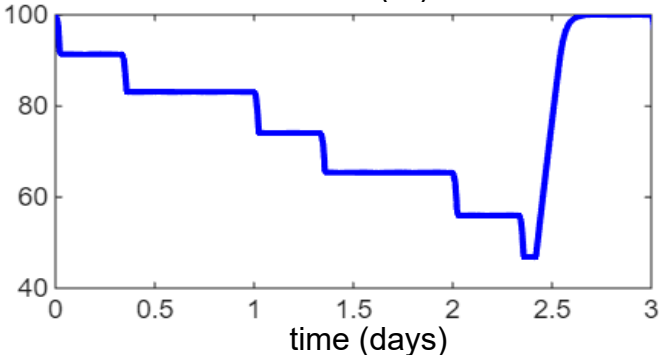
Velocity (km/h)



Simulation

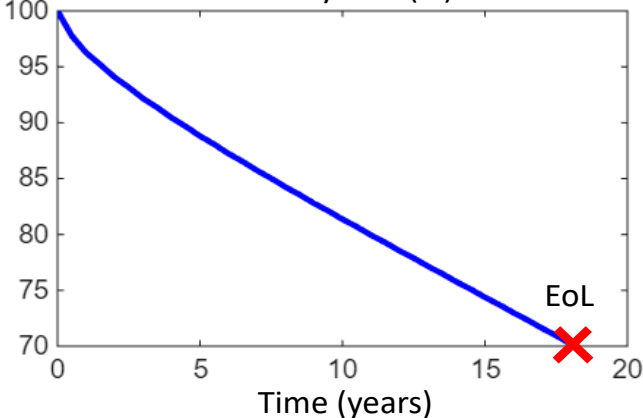


SoC (%)

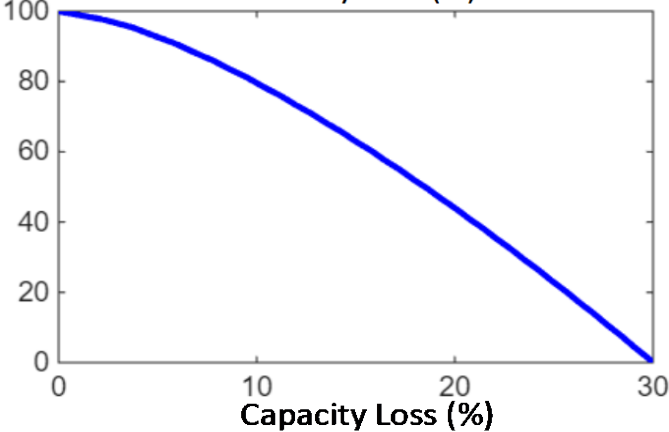


- Results

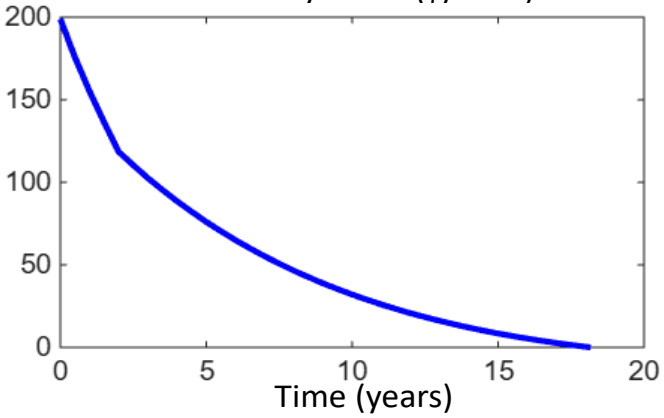
Battery SoH (%)



Battery RUL (%)



Used Battery Value (\$/kWh)



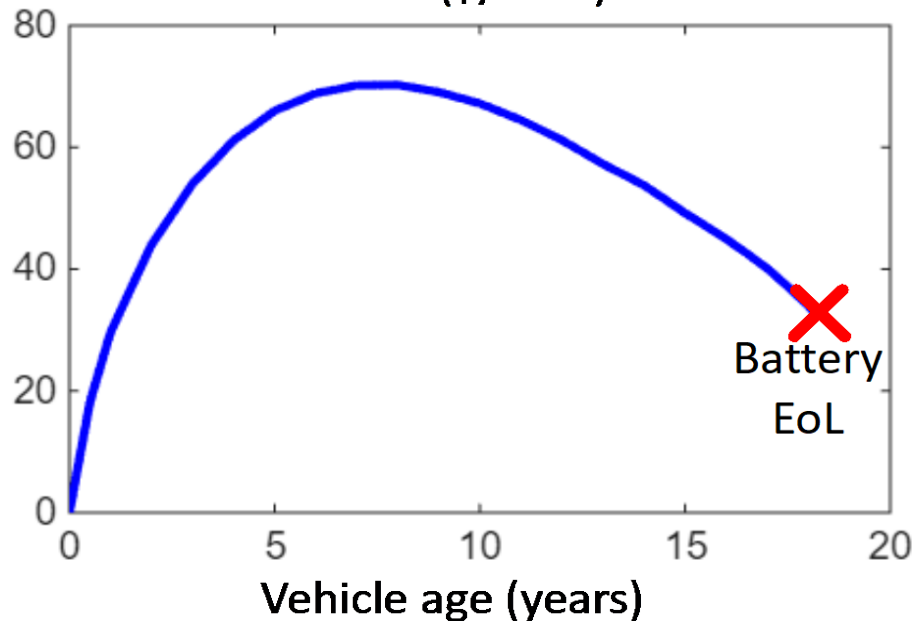
Obtain the battery value from the vehicle usage

By considering technical, economic, and preference models, we can suggest the best time to replace an EV battery

Simulation over the battery lifetime (SoH=70%)

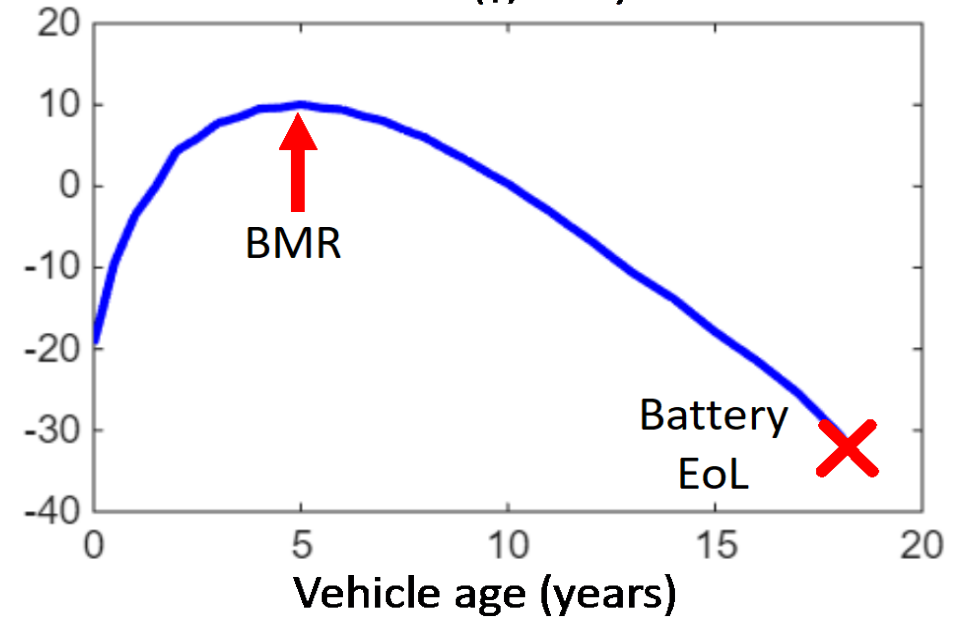
Estimation of the battery Added Value of Replacement

ARV (\$/kWh)



Estimation of the Battery Replacement Value

BRV (\$/kWh)



Value I am ready to pay to recover original range for my EV



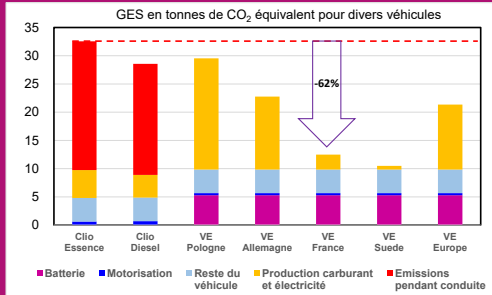
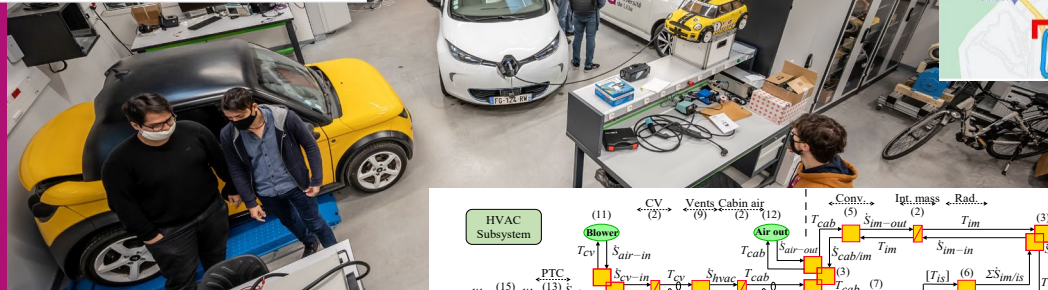
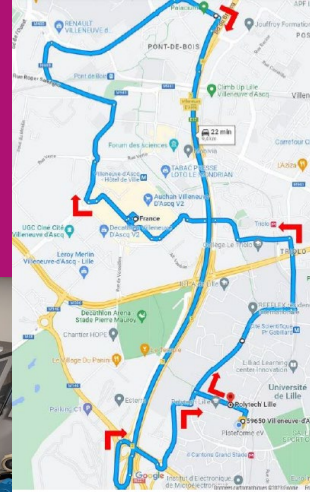
Global tradeoff including perception

$$BRV(t) = UBV(t) + ARV(t) - NBC(t) - C_{labor}$$

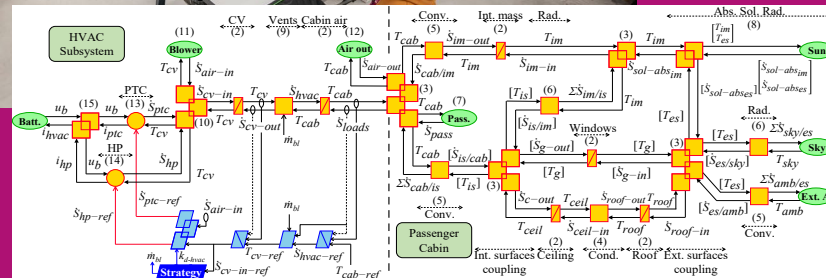
➡ BRV above 0\$/kWh between 2 and 10 years, max at 5 years



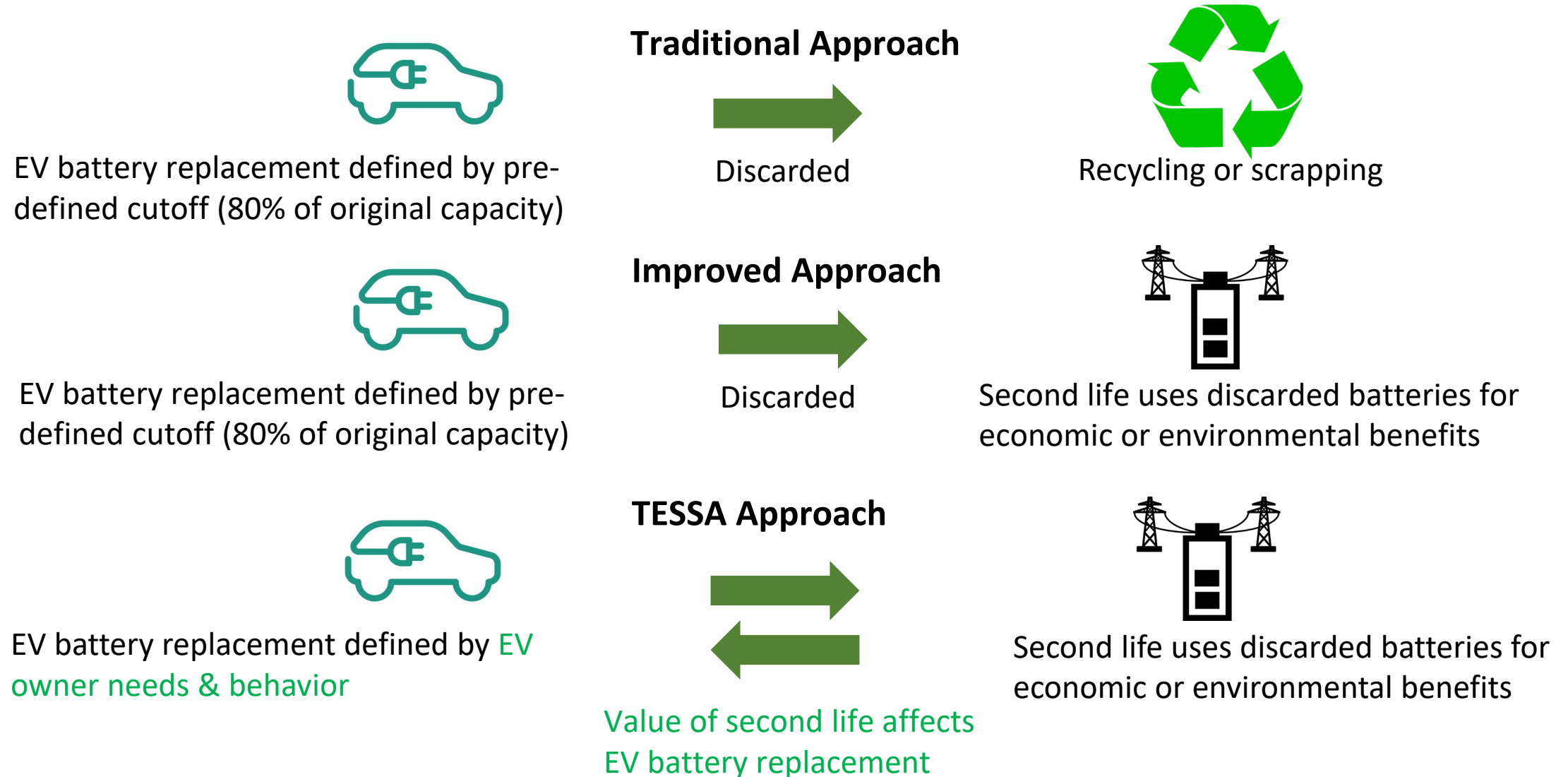
<https://cumin.univ-lille.fr/>



Our university as
an exciting living lab
towards eco-cities
through an innovative
transdisciplinary
framework !



2. If electric vehicle batteries have a useful second life, when should drivers replace them?

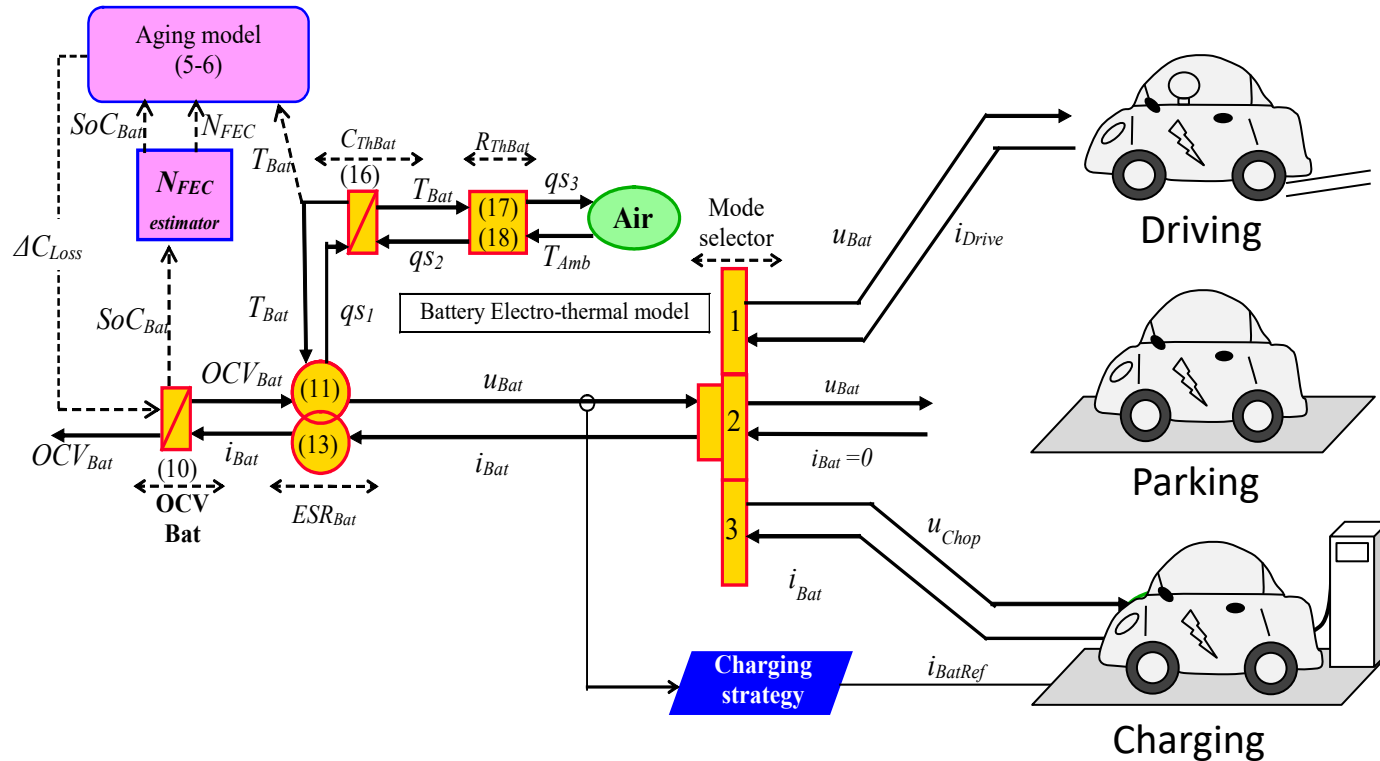


TESSA uses models and platforms from CUMIN MOUVE and EVE projects

Development of a battery aging model

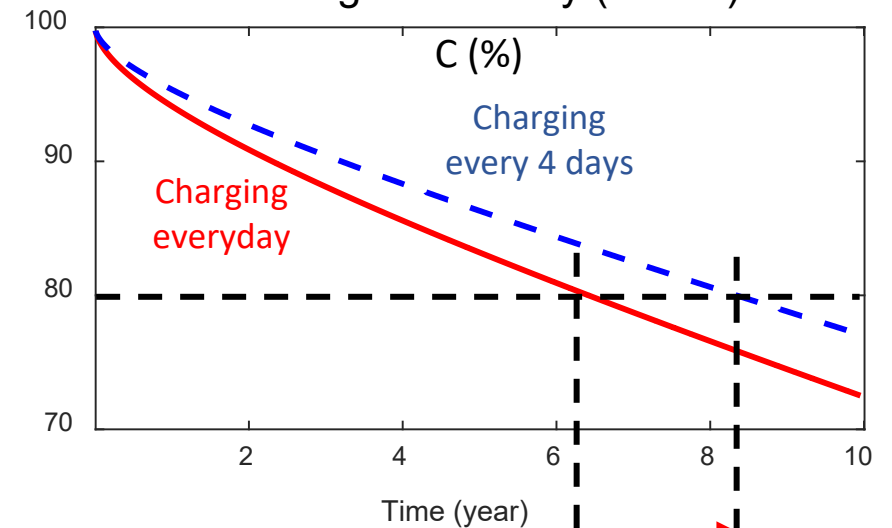


Interaction with an EV model



Charging strategy has significant effect on lifetime

Driving: 46 km/day (WLTC)



Lifetime extension by 36% for the same driving

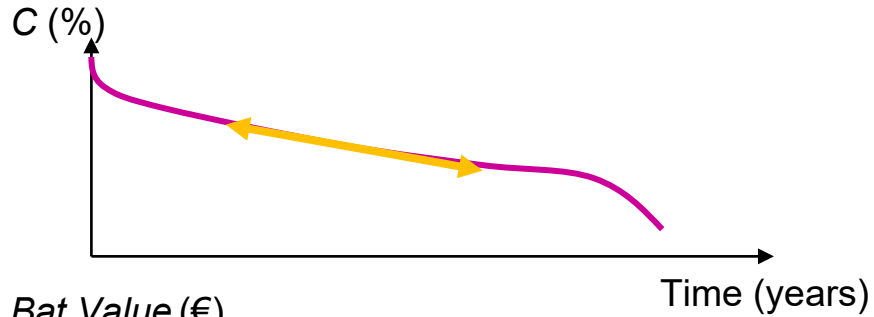
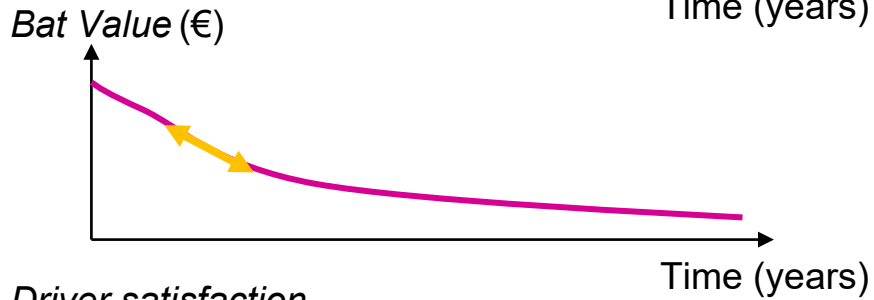
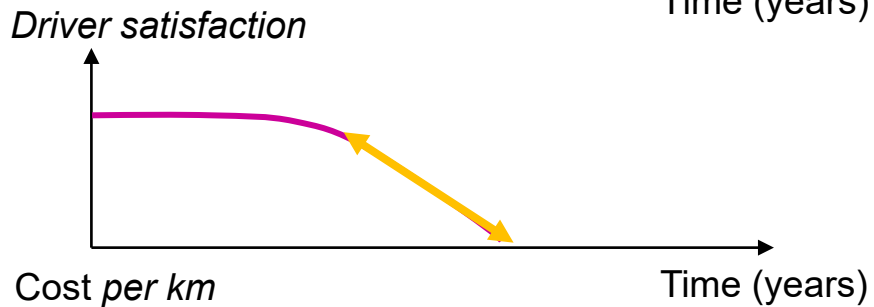
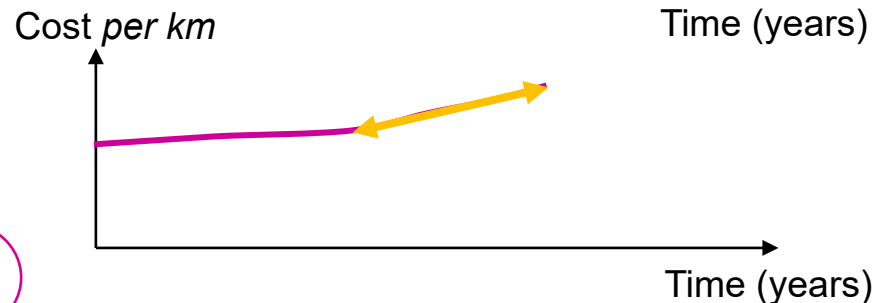
BUT...



How can we include user preference/behavior with the battery degradation?

How can we integrate the second life into a cohesive framework?

The second core element is a framework to integrate technical, environmental, and behavioral/preference elements



Important elements

- Construct the curves (data inputs)
- Account for variations across drivers, locations, battery types, etc.
- Account for seasonal cycles (winter, summer)
- Integrate environmental effects (using a life-cycle analysis approach)

A simple example for the 2nd life value of 100,000 mile EV batteries over time

Model Input	Value
Round-trip efficiency	85%
Stationary application cycling	1 cycle/day
Financial discount rate	8%
Social discount rate (DICE)	4.5%
Social discount rate (SCC Explorer)	2%
Cost of make-up electricity	\$0.15/kWh

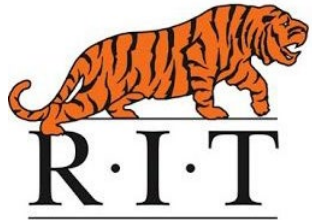
Year	New battery cost (\$/kWh)	LCOS (\$/kWh)	Second-life battery price (\$/kWh)	Present value of env. damages of new battery (\$/kWh)	Present value of env. damages when delaying new battery (\$/kWh)	Environmental benefit of SLB (\$/kWh)	Second Life Value (\$/kWh)
2025	\$139	\$0.10	\$56.46	\$17.64	\$12.94	\$4.70	\$61.16
2030	\$98	\$0.08	\$39.88	\$18.18	\$12.04	\$6.14	\$46.02
2035	\$69	\$0.07	\$28.17	\$16.92	\$10.84	\$6.07	\$34.24
2040	\$49	\$0.06	\$19.90	\$15.23	\$8.52	\$6.71	\$26.61

TESSA has an interdisciplinary challenge (and opportunity)

TESSA brings together different streams of research



Technology research at L2EP on EVs, batteries



Economic and financial modeling approaches to understand alternatives



Social science research at TVES on transport needs and behaviors



Instrumented e-vehicles and PV-based charging stations

Acknowledgements

WILL (Welcoming Internationals to Lille) programme



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